by Albert G. Snow, Jr.

Hormones & Growth Regulators Can Be Useful to Foresters

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Preface

THIS paper is based partly on an address the author presented at a meeting of the New York Section of the Society of American Foresters in Syracuse, N.Y., in January 1959.

It is not intended as a comprehensive summary of the large amount of research work being done in this very useful and interesting field. Rather, it was prepared to suggest to foresters some of the possible applications of new chemicals in forestry.

A selected bibliography has been added for the benefit of the reader who is interested in further details.

Hormones & Growth Regulators Can Be Useful to Foresters

by Albert G. Snow, Jr.*

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To save space...

... abbreviations are used for the chemical names of the growth regulators mentioned in this report, as follows:

Amo-1618	(4-hydroxy-5-isopropyl-2-methylphenyl)trimethylammoniumchloride, 1-piperidinecarboxylate.
GA	gibberellic acid
IA	beta-indoleacetic acid (also IAA and IAc)
IB	beta-indolebutyric acid (also IBA and IBc)
IPC	O-isopropyl-N-phenyl carbamate (also IPPC)
MH	1,2 dihydro-3,6-pyridazine-dione (Maleic hydrazide)
NAA	alpha-napthaleneacetic acid (also NA and NAc)
NAD	alpha-napthaleneacetamide (also NAd and Nacet)
NBA	alpha-napthalenebutyric acid (also NB)
p-CPA	para-chlorophenoxyacetic acid (also ClPA and CPA)
2,4-D	2,4-dichlorophenoxyacetic acid (also DCPA)
2,4,5-TP	2,4,5-trichlorophenoxyproprionic acid

Chemicals & Trees

TREES, like other plants, contain many natural chemicals of the sort that we call hormones. Research is gradually revealing that, in the behavior of a tree, these chemicals may be almost as important as the basic influences of heredity and environment.

In early concepts, the term "growth regulator" was used to mean chemical substances that, though they were believed not to occur in plants, yet would often influence plant response in much the same way as hormones do. Now refined methods of chromatography are producing evidence that plants themselves contain many growth-regulating chemicals that previously were thought to occur only on the laboratory chemical shelf.

For us foresters, it is important to have a common concept of chemical growth regulators so that we may apply this knowledge in attacking our forestry problems.

To begin with, we must recognize that plant or tree responses--in growth, flowering, root initiation, and other developmental processes--are governed by inherent genetic qualities.

Second, we ought to know that manipulation of one or more factors of the environment, such as mineral nutrition balance, photoperiod, or temperature and moisture regimes, will also produce variations in response.

And third, we are learning that applied chemical growth regulators often will modify the responses that are governed by heredity, or will induce responses that are nearly identical with those induced by environment.

Responses Produced

Growth regulators and hormones produce a variety of responses in plants. Some chemical regulators, under different conditions, can even produce opposite effects on the same plant. Depending on the concentration used, the stage of growth, and environmental conditions, the chemical may either stimulate growth of the plant--or kill it.

Some of the ways that chemical growth regulators may be used to influence plant behavior are:

To control wound-healing, bud growth, and dormancy of all plant parts, including seed.

To control stem elongation, shortening, or thickening.

To inhibit sprouting.

To prolong or shorten the vegetative cycle.

To assist in vegetative propagation from cuttings or in grafting.

To control root proliferation and growth.

To control flowering and reproductive plant structures.

To perform selective pesticidal action.

To control abscission of flowers, fruits, and other plant parts.

To control transpiration, respiration, photosynthesis, and many other plant processes.

To control growth of micro-organisms in the soil.

And there are many others.

A precise definition of potential tree responses to applied chemical growth regulators is difficult because of the interrelationships of roots, tops, and flowers. Chemicals beneficial to flower production may decrease growth; this is only one of many possible related effects. Also, in forestry we are concerned with all of these aspects in problems of forest management, watershed management, forest fire control, forest diseases, and forest insects. Growth regulators may be important in all of these fields. The following discussion touches on only a few highlights in each of these major lines of forestry activities.

Possible Uses

Forest Management

One objective that is common to many phases of forest management is to obtain adequate regeneration. With pine, for example, this goal is more likely to be reached if pine cones contain full complements of viable seed. In some horticultural species, napthaleneacetamide (NAD) treatment during pollination time increases seed production greatly. This would be a desirable effect in valuable tree-seed

orchards, where the investment is high and the maximum production of seed is very important.

It is possible that NAD and para-chlorophenoxyacetic acid (p-CPA) would also be useful in forest genetics work, since we know they increase the set of seed from cross-pollinations.

Male and female flowers on different trees often bloom at different times. The time of flowering might be selectively controlled with the growth-retarding action of napthaleneacetic acid (NAA) or other regulators, and this might enable some crosses to be made that would otherwise be impossible.

The growth-controlling effects of some of the quaternary ammonium compounds might be put to use in forestry in a number of ways. One of the most active of these has a 78-letter name[1]; for convenience we call it Amo-1618. With this growth regulator, moderate to extreme inhibition of stem elongation is obtained, depending on the concentration used, species, and environmental factors. At appropriate rates of application to the soil, Amo-1618 may remain effective for a long time. Spray treatments are also effective because of its ready solubility in water. In annuals, this substance is translocated to the seed, and a noticeable inhibitory response is carried over for at least two generations.

Elm, maple, and oak are moderately responsive to Amo-1618. This suggests that conifers might be brought through in cut-over areas with heavy hardwood growth if Amo-1618 were applied to the cut hardwood stumps or sprouts. The growth-retarding effect from a single application might be enough to keep the sprouts controlled until the conifer seedlings had grown beyond their influence.

In forest nurseries, the growth rate of some species is often controlled by regulating moisture and fertilizer applications. Amo-1618 might be a solution to growth control in these cases. With growth controlled, more fertilizer and water may be used, which might result in production of healthier stock better conditioned to withstand adverse outplanting situations.

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[1] (4-hydroxy-5-isopropyl-2-methylphenyl)trimethylammoniumchloride, 1-piperidinecarboxylate. Chemical names and abbreviations of other compounds are listed facing page 1.

Another plant-regulating chemical that is now receiving much attention is gibberellic acid (GA). This compound may also prove useful in forest-tree nursery operations, but in a different way than Amo-1618. The specific applications are suggested by the special effects produced. Rapid lengthening of stems for a few weeks is a common response, though many other effects are obtained. The results depend on strength of treatment, species, stage of development, and environmental conditions. Plants flower faster or slower; grow thinner or thicker stems; develop more foliage or more seed; overcome dwarfism; rouse from dormancy. Perhaps we can use some of these attributes of GA to reduce the time some species remain in the seedbed, to produce more plantable stock, and to obtain stock better suited to particular planting-site situations.

The use of growth regulators in the vegetative propagation of trees, particularly in rooting cuttings, is well established, though by no means have all avenues been explored. A few of the effective compounds include indole-

Figure 1.--Effect of a phosphonium compound on the growth of a hybrid petunia (variety Ballerina). The soil was amended with (left to right) 0, 125, and 500 pounds per acre of 2,4-dichlorobenzltributylphosphonium, which retards growth. The species selectivity of this and similar compounds suggests possibility for weed control in tree nurseries, provided the tree species grown is not adversely affected.

Figure 2.--Effect of gibberellic acid on the growth of loblolly pine. When 2-year-old trees were sprayed with gibberellic acid (concentration of 400 ppm) at the time buds were opening, height growth and diameter growth were doubled in one season (tree on right). Tree on left is untreated tree of same age.

butyric acid (IB), NBA, NAA, and 2,4,5-TP. The first two mentioned have the advantage with some species of not suppressing vegetative growth after cuttings are rooted.

Only a few investigators have used growth regulators to stimulate wound-healing in trees. Of those tried (such as IAA, IB, NAA, CPA, and 2,4-D), few gave positive results, and then only with a few species. Glutathione stimulated wound-healing in sugar maple, and CPA and cysteine HC were weakly effective with red oak. All others tried were ineffective or inhibitory under the conditions used.

Figure 3.--Effect of Amo-1618 on the development of a tall-growing type of salvia (scarlet sage). The plant on the left is the untreated control. The other three plants were sprayed with Amo-1618 in increasing concentrations (10, 100, 1000 ppm). The higher concentrations accentuate 'dwarfism' by suppressing stem elongation.

Recent work with red pine[2] shows that typical springwood cells have been produced in otherwise summerwood-producing seedlings by application of IAA. This might influence specific gravity and, indirectly, pulp yields. Thus one should consider *all* responses from growth regulators, because treatments designed to increase growth might result in lower ultimate yields in terms of usable wood.

Fire Control

Firebreaks of many different types are used to protect forest investments. Some of these firebreaks depend on a grass or herbaceous cover to maintain a low fuel barrier.

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[2]Larson, P. R. A physiological consideration of the springwood-summerwood transition in red pine. (In press.)

However, toward the end of the growing season this ground cover often turns brown and becomes more hazardous.

It is known that Amo-1618, besides inhibiting growth, causes some herbaceous species, particularly legumes, to remain in a healthy green state until frost comes. The use of Amo-1618 and legumes in firebreaks would increase fertility and eliminate the late-season hazard from dry materials. With soil treatments, a residual effect lasting several years might be obtained both through a hold-over in the soil and through the seed.

Watershed Management

The same relationships mentioned for fire control might also apply in watershed management. In addition to herbaceous ground cover, there may be times and places where brush cover would also be desirable. Dwarf types, which

Figure 4.--Effect of gibberellic acid on the growth of a dwarf-type azalea. The plant on the right was sprayed with gibberellic acid at a concentration of 100 ppm at the time of bud opening. Six months later the shoot length was over two times that of the untreated control on the left. This extra shoot length facilitates vegetative propagation from cuttings.

could be produced by Amo-1618 and other growth regulators, might be more desirable for reducing water use and increasing water yields, particularly around impoundments.

Forest Diseases

Growth-regulator chemicals might prove useful in the control of Dutch elm disease. According to recent experiments,[3] 4,5-dimethyl-2-thiazolylmercaptoacetate and 2,3,5,6-tetrachlorobenzoic acid applied to elms just before budbreak delay or inhibit formation of the large springwood vessels. Since spores of the fungus causing the disease are introduced into the tree in the spring by the feeding of certain beetles that emerge in large numbers at this time, and are carried to other parts of the tree in the sapstream, mainly through these springwood vessels, delay in large-vessel formation tends to reduce spread of the fungus. So far, attempts to prevent spread of the fungus by delaying large-vessel formation have been only partially successful. Studies are being continued with other methods of application and other growth substances.

Relatively little use of growth regulators has been made in controlling or influencing tree diseases, yet the potentials may be great. Some chemicals, such as 2,4-D, control certain fungi but fail to influence others. IA, IB, and NAA increase the incidence of infection in cuttings by *Fusarium* species.

Indirect control of white pine blister rust is being done by killing Ribes with mixtures of 2,4,D and 2,4,5-T. A Nectria canker on apple has been controlled with indolebutyric acid (IB), though this chemical was only very weakly toxic on the fungus grown in pure culture. Canker diseases on forest trees, such as *Nectria* and *Strumella*, might be controlled with proper growth regulators.

Stem dieback, a physiological disease of orange trees that leads to stem and fruit shrivelling, was reduced markedly by sprays of 2,4-D. This opens up the possibility of controlling some of the physiological diseases of forest tree species with selected growth regulators.

[3] Cooperative Regional Project NE-25 'Biology and Control of Wilt Pathogens'; Conn., Mass., N. J., N. Y., Pa., R. I., W. Va., and U.S. Dept. Agr.--Agr. Res. Service, Forest Service.

A growth regulator named maleic hydrazide (MH) has been used with only partial success in attempts to delay shoot growth of pine in order to interfere with shoot moth development. Other compounds are available for the same purpose, such as NAA, 2,4,5-T, and IPC. These, if used in proper concentrations and with correct timing, might be more effective than MH in retarding shoot growth.

A potentially important weapon in our long war on harmful forest insects has emerged from recent basic research in insect physiology. Two new hormones have been isolated from insects, with the initial impetus coming from work with gypsy moth. One of these, called Ecdysone, triggers the moulting process. The other, called "juvenile hormone", delays the insect from passing into its next stage. These compounds have been isolated and their chemical formulas determined, so they can be prepared synthetically in the laboratory.

Exploratory tests have shown that these two new hormones, in very weak concentrations, can kill insects. Their future use in the control of forest insects may go a long way toward providing a substitute for some of the chemicals now widely used, but without the undesirable side effects on other forms of life in the forests.

In Conclusion...

Finally, a word of caution. When considering the use of special chemicals, let us be sure to recognize possible secondary effects. These effects may not all be beneficial.

But also, let us not curb our imaginations, since there are many possible ways of influencing tree growth and other related phenomena. The proper hormone or growth regulator may now be waiting for us to put it to use in solving some of our forestry problems.

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